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2013

document version
Early version, also known as pre-print

Faculty of Economics and Business Administration

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Research Memorandum 2013-24

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TRAFFIC INCIDENT AND DISASTER MANAGEMENT IN THE NETHERLANDS: CHALLENGES AND OBSTACLES IN INFORMATION SHARING

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Abstract - *Disaster Management and Traffic Incident Management involves the coordinated interactions of many public and private actors. On many levels, there is clearly a strong relation between the road infrastructure and the effective handling of large scale disasters. To support these tasks in an effective way, netcentric information systems are increasingly being seen as an important constraint to improve the cooperation between different emergency services. However, in the field of information systems there are many challenges and obstacles. Information, communication and coordination tasks, and especially problems in information quality, are identified as the main hurdles. This paper addresses, from a broad perspective, the relation and challenges between the two related fields.*

Key-words - *Traffic Incident Management, Disaster Management, Information systems*

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1. INTRODUCTION

We live in an uncertain environment where the existence of risks prompts innovation and modernization. Clearly, risks are an important characteristic of our modern society. Economic globalization and its related transport of goods and people all over the world are the driving force of coping with risks and vulnerability. The world's population rose in 2011 to around 7 billion people. More than 50 per cent of the world's population now live in urban areas (United Nations, 2009). The increase in population and the associated density of people has led to an intensity of production, transportation and decreasing travel behavior with more trips over longer distances.

The rising trend of urbanization is caused by a number of different factors such as access to a higher level of facilities (e.g. theatres, shops, restaurants) and the presence of concentrations of employment with greater chances on economic and social wealth. When more people move to live in the city, this increases urban density and the growth of the urban area. Urban sprawl has been recognized as a one of the problematic aspects of metropolitan areas. This also has a negative impact on the quality of the social and economic environment (e.g. longer travel times, higher air pollution and a higher risk of traffic accidents).

The year 2010 was one of the worst years of devastation, with the highest number of natural disasters in the past 30 years. 725 extreme weather phenomena caused billions of euros of damage and the loss of thousands of people's lives. Natural catastrophes do not respect national borders. Flooding, fires, landslides, and earthquakes cannot be prevented from happening, but a good prevention measure can help to save lives and reduce economic damage.

The Netherlands is the only European country which is in the world's top 10 most densely populated areas, with approximately 403 people / km^2. As a result of the large number of road users on many road networks, congestion occurs frequently, mainly at the same bottlenecks. This leads to congestion and travel time losses. When congestion is caused by regular bottlenecks, travellers can globally assess how much time loss is due to congestion on most routes. It is, however, much more difficult to estimate the travel time losses caused by irregular and unexpected situations, such as traffic incidents, adverse weather conditions, road works, and events.

The goal of sustainable mobility is one of the biggest challenges in modern traffic management. Different instruments have been proposed in the past to tackle congestion in metropolitan areas: road pricing, fuel taxation, improving public transportation, and so on. Efficient road networks are increasingly seen by governments across Europe as being the key to supporting and sustaining economic growth, as they enable the movement of goods and services around the country (Directive 2001/370/EC; 2011/144/EC). Economic constraints are causing national road authorities to innovate, as they look for cost-efficient ways to tackle congestion and develop more effective traffic Incident Management (IM) measures. This has led to an emphasis in many European countries on the better use of existing infrastructure and

IM capabilities, rather than on investing in more costly systems, equipment and working methods.

Traffic IM can be seen as a special case of (simplified) crisis or Disaster Management (DM) in terms of organization and work processes. In 2005, an advisory committee to the Dutch Ministry of Internal Affairs and Kingdom Relations concluded that enabling shared access to information between different emergency services is the main bottleneck when it comes to effective inter-agency crisis response in the Netherlands (ACIR, 2005). This conclusion is in line with improving cooperation between the emergency services for traffic incident management. Successful traffic IM presupposes a multidisciplinary approach and involves the coordinated interactions of multiple public agencies and private-sector partners. Since the formal introduction of IM in the early 1990s, the importance of cooperation between the different actors in the IM network has increased, and is nowadays an important condition for further improvement of the IM process. This cooperation is clearly defined in the IM policy rules (Dutch Ministry of Transportation and Water Management, 1999). Organizations which are responsible for traffic IM are the road authority and public emergency services (Police, Fire Brigade, and the Medical services). Private IM organizations main tasks are towing, repair and insurance services. Cooperation has become a crucial factor to apply successful IM and DM. An important constraint for improving cooperation is shared access to information. Information technology and the introduction of new information concepts is essential to improve information sharing and the decision making process for emergency responders. The aim of this paper is to give an overview of the two related fields (IM and DM), with a special emphasis on information sharing, communication and coordination

2. GENERAL OVERVIEW OF CRISIS MANAGEMENT

2.1 Definitions and policy goals

Any discussion of DM often depends on a common understanding on disaster taxonomy. In the literature there is no general agreement of the definitions and taxonomies. For example, Green and McGinnis (2002), describe three classes as the highest order range of disaster events: natural disasters, human systems failures, and conflict based disasters. In the literature there are many different taxonomies of disaster (see e.g. Lerbinger, 1997; Duke and Masland, 2002). Urban areas are particularly vulnerable, not only because of the concentration of population but also due to the interplay that exists between people, buildings, and technological systems. Disasters pose a threat to sustainable development, as they have the potential to destroy decades of investment and effort, and cause the diversion of resources intended for primary tasks such as education, health and infrastructure.

A disaster is a major accident or other incident involving the life and health of many people, the environment or major material interests which are all seriously threatened or harmed, while the coordinated use of services or organization from different disciplines is required to remove the threat, tackle or it limit the adverse effects (Law on Dutch Safety Regions, 2010). Their consequences are so great that the emergency services (police, fire, ambulance, hospitals) are not able to handle the incident by normal means and structure. We therefore need additional resources and a special organization to be established.

In the Netherlands a '*crisis'* is seen as an umbrella term[5]: it covers concepts such as incident, emergency, disaster, serious accident, which are special forms of a crisis. From this perspective, '*disaster response*' is a particular form of '*crisis management*'. Under the Law on Dutch Safety Regions (2010), a *crisis* is defined as '*a situation where the vital interests of society is affected or likely to be affected*'. We can speak of a crisis when national security is at stake because one or more vital interests are affected, and when regular structures and / or resources are not sufficient to maintain stability. In other words, if large parts of society are at risk, a cross-departmental coordinated action is therefore necessary to eliminate the threat and reduce the negative effect (BZK, 2009). In the Netherlands, the policy for protecting national safety and security is based on securing 5 pillars: territorial security, economical stability, ecological safety, physical safety, and social and political stability.

A 'traffic incident' is defined as "*an unforeseen (unpredictable) event that impacts on the safety and the capacity of the road network, and that causes extra delay to road users*" (EasyWay, 2011). The term 'incident' is clearly defined in the Dutch policy rules. Incidents are "*all the events (such as accidents, dropped cargo, stranded vehicles, collisions to incidents involving hazardous materials), which affect (or may effect) the capacity of the road and hinder a smooth the flow of traffic with the exception of breakdown vehicles on the hard shoulder where there is a minimal and acceptable risk regarding the traffic flow and safety and of the other traffic*" (Dutch Ministry of Transportation and Water Management, 1999). Traffic incidents have a significant impact on a reliable transport system. They form an increasing cause of traffic jams, congestion and vehicle lost hours. Besides the direct impacts in terms of property damage, injuries, fatalities and other road safety effects for road users in the vicinity of traffic incidents, they are also relevant for mobility. Incidents can quickly lead to congestion and associated travel delay, wasted fuel, increased pollutant emissions and higher risks of secondary incidents.

Traffic Incident Management (IM) has a long history, the origin of which can be found in the US (Koehne *et al.*, 1991). To "keep Washington on the move", an Incident Response programme has been initiated by the Washington State Department of Transportation (WSDOT), which started as a pilot in 1990. The Netherlands is the first country in Europe where a formal structure for IM was introduced in the early 1990s (Steenbruggen *et al.*, 2012a). Since then, other EU countries have followed by implementing different IM measures to tackle mobility and safety problems. Central elements in different existing IM definitions are the planned and coordinated measures for the safe and quick restoration of the situation to

[5] http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/2009/11/23/nationaal-handboek-crisisbesluitvorming.html

normality (Steenbruggen *et al.*, 2012b). IM is, in general, the policy that through a set of measures, aims to reduce both the negative effects on the traffic flow conditions and the effects on safety, by shortening the period needed to clear the road after an incident has happened. It can also been seen as a process to detect, respond and remove traffic incidents and to restore traffic capacity.

2.2 Types and numbers

The Netherlands is by far one of the safest countries in the world. It is not only geographically very stable but rarely has any natural disasters such as flooding, tornadoes, hurricanes, tsunamis, or earthquakes. However, because it is one of the most densely populated areas in the world, even small disasters can have a huge impact on the environment. Figure 1 gives an overview of the main disasters in the Netherlands between 1945 and 2012.

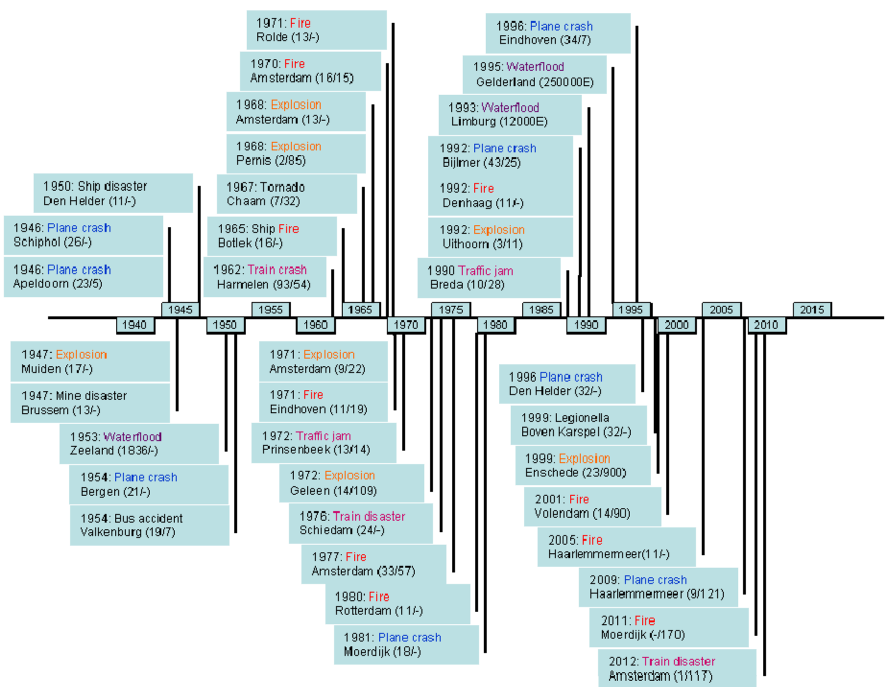

Figure 1: Chronological overview of large disasters in the Netherlands (between 1945-2012)

Floods, even which actually happened only three times in this period, have the largest impact on great parts of the Netherlands in terms of casualties, mainly because a large part of the country lies below sea level. For example, one of the biggest natural disaster in European modern history took place in the Netherlands with over 1800 people killed and many more injured.Other main categories, in terms of number occurring, are plane crashes, fires, and explosions. Table 1 summarizes these disasters in terms of types, numbers, casualties, injured, and evacuated.

Table 1: Number and type of large disasters in the Netherlands (1945 – 2012).

Type	Plane crash	Train disaster	Traffic disaster	Ship disaster	Extreme weather	Floods	Mine Disaster	Fire	Explosion	Legio nella	Total
Number	8	3	3	1	1	3	1	11	7	1	**39**
Casualties	206	118	42	11	7	1836	13	149	81	32	**2495**
Injured	158	171	49	0	32	unknown	0	267	1127	0	**1904**
Evacuated	0	0	0	0	0	350000	0	0	0	0	**350000**
Total	**364**	**288**	**91**	**11**	**39**	**351836**	**13**	**516**	**1208**	**32**	**354398**

Since the 1970s, there have been an increasing number of registered traffic incidents on the Dutch road network with nowadays a total of approximately 100.000 per year (Leopold and Doornbos, 2009). They vary from vehicle breakdown till serious road accidents with material damage and fatal causalities, which account for approximately 270 incidents a day. This leads to the need to structure IM activities in terms of organization, work processes and cooperation. Since 1994, there has been a significant reduction to reduce the incident time (See Table 2).

Table 2: Number of incidents in the Netherlands

	Breakdown vehicles		**Only material damage**		**Heavy accidents (injured, trucks)**		**Unknown**
number of incidents	61,287		12,926		1,720		24,681
percentage of total incidents	61%		13%		2%		24%
contribution to reduce incident time (1994-2008)	36% cars	22% trucks	26% cars	13% trucks	17% Cars	10% trucks	-
mean contribution to reduction time (1994-2008)	approximately 30%						
contribution to reduce incident time (2004-2008)	13% cars	6% trucks	9% cars	3% trucks	5% cars	2% trucks	-
mean contribution to reduction time (2004-2008)	approximately 10%						

Source: Leopold and Doornbos (2009).

At the beginning of the 1970s, there were over 3000 fatal casualties (see Figure 2). The main causes of road deaths are speeding, driving under the influence of alcohol or drugs, and non-use of seat belts[6]. Since then, the number of fatal casualties has been drastically reduced by Governments which have introduced a number of specific measure and comprehensive laws to cover the main risk factors. By 2020 the Dutch government wants to reduce the number of fatal casualties to 500, and the number of injured to 10,600. In 2010 there where 640 fatal casualties and approximately 17,000 injured. The goals are defined in the strategic plan *Traffic Safety* (Dutch Ministry of Transportation and Water Management, 2008) and includes an action programme which describe the specific measures.

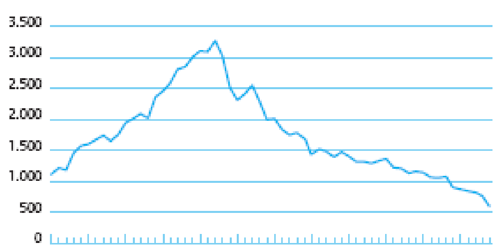

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Figure 2: Total Number registrered numbers of fatal casualties.
Source: Dutch Ministry of Transportation and Water Management (2010).

2.3 Organization

Transportation operations and public safety operations are intertwined in many respects. Public safety providers, e.g. through law enforcement, fire and rescue, and emergency medical services, can ensure safe and reliable transportation operations by helping to prevent crashes and rescuing accident victims. On the other hand, the transportation network enables emergency organizations access to incident locations, and, increasingly, provides real-time information about road and traffic conditions.

Natural catastrophes do not respect national borders. In 2001, the EU Member States initiated what is called the community procedure in order to better coordinate DM and civil protection. The European Commission installed the Monitoring and Information Centre (MIC) to forward distress calls more quickly. The European Commission is attempting to facilitate the cooperation between Member States in the field of civil protection in order to speed up the resources of DM. Therefore, they have built national, bilateral and multilateral modules. In practice, the responsible authorities have to manage disaster preparedness management plans and multinational teams. The European Commission are also trying to facilitate the cooperation between Member States in the field of civil protection, in order to speed up the deployment of DM resources. The Euro-Atlantic Disaster Response Coordination Centre (EADRCC) is another European example of crisis coordination.

In the Netherlands, the way how to organizing DM has a long history. Just after the Second World War, the thinking on this was dominated by fear of war and natural disasters such as the serieus flood of 1953. In the report *Nota hulpverlening bij ongevallen en rampen* (in English: Emergency aid for serious accidents and disasters) (1975), the Dutch gouvernment conclude that the local potential was insufficient. From 1975 till 1994, a number of legal and organizational measures were taken, such as introducing regional fire brigades in 1976, the introduction of the *Brandweerwet* (in English: Law on national Fire Brigade) (1985) and the *Rampen Wet* (in English: Law on national Dutch Disasters) (1985).

In 1994, the police were regionalized, and the municipal state police and national police were reorganized into 25 regional and 1 central unit. In addition, the three disciplines (the fire brigade, the medical services, and the police) are also physically located (e.g. co-located) at the same location.

Different disasters, such as the firework explosion in Enschede in 2000, and the café fire in Volendam in 2001, made clear that there was still a long list of necessary improvements. In 2004, the *Wet kwaliteitsbevordering rampenbestrijding* (in English: Law on quality improvement of DM) (2004) was introduced. Recently in 2010, the new Law on Safety regions came into force, based on different experience and conclusions from different disaster evaluation studies. Hereby, the organization of the Fire Brigade and Medical aid for accidents and disasters, and other type of disaster and crisis were placed under the responsibility of one

central authority. With this new coordinated approach the emergency services can be managed more effectively. Central elements are reporting and alerting, escalating (upscaling and downscaling); leadership and coordination, and information management.
There is great variety in the national road administrations in Europe. Examples of organizations are the Conference of European Road Directors (CEDR), the European Construction Technology Platform (ECTP), and the European Road Transport Research Advisory Council (ERTRAC). The Transport Research Committee (TRC) is another forum for strategic coordination in Europe.
In the Netherlands, the public IM emergency services are the Road authority, the Police, the Fire Brigade, and the Ambulance services. Rijkswaterstaat (RWS) has, under the *Rijkswaterstaatworks Management Act* (1996), the public responsibility for the efficient and safe use of the main road network. Towing, repair, and insurance services are the main tasks of private IM parties. The operational IM organization consists of the foundation in 1997 of the Incident project office. On a tactical level, the IM platform's task is to implement the national regulations and different IM measures. To this end, the platform has formulated agreements about the cooperation between the emergency services on motorways. Several emergency services are represented within this organization, e.g. the police, the fire brigade, transport authorities, motorway operators, and insurance companies. On a strategic level, the IM Consulation was established in 2008 (Steenbruggen *et al.*, 2012a).

2.4 Work processes

In the literature there are different definitions of the DM process phases (see Table 3). DM involves a cycle of the organized effort to mitigate against, prepare for, respond to, and recover from a disaster (FEMA, 1998).

Table 3: Differences in the definition of Disaster Management (DM) process phases

	United States FEMA, 1998	**Hale *et al.* (2005)**	**Europe PSC Forum**[7]	**Netherlands Safety regions (2011)**	**Netherlands Rijkswaterstaat (2012)**
Risk control	mitigation	prevention	mitigation	prevention	pro-action
			prevention		prevention
Disaster Management	preparedness	response	preparation	preparation	preparation
	response		response	response	response
	recovery	recovery	recovery	recovery	recovery

The Dutch Ministry of Internal Affairs introduced the *Referentiekader Regionaal Crisisplan*, (Coordinated Reference Framework) (2009), a structure which indicates who is responsible for different scales of incidents: 1). operational coordination in the field; 2). operational coordination on the regional level; 3). policy coordination on the local level; and, 4). policy coordination on the national level (GRIP, 2006). Traffic IM can be seen as a GRIP-0 level.

[7] **www.publicsafetycommunication.eu/**

The handling of an incident can be described in terms of the duration of an incident. In the literature there is no general agreement on the different phases of IM (see Table 4: Steenbruggen *et al.*, 2012a). In the Netherlands we use a simplified version of the IM phases of Zwaneveld *et al*. (2000) which is subdivided into four phases: alerting, response and arrival, action, and normalization phase (Dutch Ministry of Transportation and Water Management, 2004). An attempt to create a shared European agreement on process phases can be found in CEDR (2011).

Table 4: Differences in the definition of traffic IM process phases (Steenbruggen *et al.*, 2012a)

United States **Federal Highway** **Administration (2000)**	**Europe** **CEDR (2011)**	**Europe** **EasyWay (2011)**	**Netherlands** **Zwaneveld *et al*. (2000)**	**Netherlands** **Red-Blue booklet (2004)**
detection	discovery	discovery	detection	alerting
verification	verification	verification		
response	initial response	initial response	warning	response
			driving or arrival	
site management	scene management	scene management	operation or action	action
clearance	recovery	recovery	normalization	normalisation
	restoration to normality	restoration to normality	flow recovery	
	normality			

2.5 Conclusions

The main differences between traffic IM and DM are summerized in table 5. In the next section we look specifically at the role of information sharing between the emergency services.

Table 5: Summerized overview of the differences between traffic IM and DM

	Traffic Incident Management	**Disaster Management**
Definition	A planned and coordinated process to detect, respond and remove traffic incidents and restore traffic capacity as safely and quickly as possible (US Federal Highway Administration, 2000).	A disaster is a continuously unfolding situation, marked by changes in urgency, scope, impact, the types of appropriate responders, and the responders' needs for information and communication (Janssen *et al*., 2010).
Type of Event	An 'incident' is defined as an unforeseen (unpredictable) event that impacts on the safety and the capacity of the road network, and that causes extra delay to road users (EasyWay, 2011); Incidents are all the events (such as accidents, dropped cargo, stranded vehicles, collisions with incidents involving hazardous materials), which affect (or may affect) the capacity of the road and hinder the smooth flow of traffic (Dutch Ministry of Transportation and Water Management, 1999).	Unpredictable, dynamic and complex nature of the environment in which multiple groups of professionals need to cooperate (Kapucu, 2006); Response to disasters, whether natural (e.g. floods, earthquakes) or human-induced (e.g. terrorist attacks), is a complex process that involves severe time pressure, high uncertainty, and many stakeholders, which results in unpredictable information needs (Lee *et al.*, 2010).
Goals	Mobility and safety issues. The list of priorities are: the safety of the emergency workers, traffic safety, treatment of casualties, maintaining the traffic flow and vehicle/cargo salvaging (Dutch Ministry of Transportation and Water Management, 1999).	Protecting homeland national safety and security issues. In the Netherlands the governmental national policy is to secure 5 pillars of national safety: territorial security, economical stability, ecological safety, physical safety, and social and political stability (BZK, 2009).
Organization	Interaction with familiar faces (Auf der Heide, 1989); Hierarchy in routine circumstances used to establish control, specify tasks, allocate responsibilities and reporting procedures, and presumably achieve reliability and efficiency in workflow.	Interaction with unfamiliar faces (Auf der Heide, 1989); Under urgent, dynamic conditions of disaster, however, hierarchy procedures almost always fail (Comfort and Kapucu 2006). Traditional models of coordination are inadequate for volatile and dynamic situations (Faraj and Xiao 2006). There is a need to develop flexible coordination mechanisms that can be easily customized for the specific situation and provide better supports for improvized responses (Chen *et al*. 2008; Mendonca 2007).
Communication	Use of familiar terminology in communication. Communication frequencies adequate for radio traffic (Auf der Heide, 1989).	Communication problems with persons who use different terminology. Radio frequencies often overloaded (Auf der Heide, 1989). High uncertainty, a greater density of communication and the rate of decision-making increasing particular at lower levels.
Coordination	Hierarchical coordination works fine for daily, routine operations. Hierarchical coordination, characterized by structural features such as standardization, specialization, and formalization, enable the steady, efficient functioning of relief agencies in stable (non-disaster) environments (Bharosa *et al.*, 2011).	Hierarchical coordination severely limit the flexibility public safety networks need to cope effectively with complex, ambiguous, and unstable task environments (Bharosa *et al.*, 2011).
Resources	Management structure adequate to coordinate the number of resources involved (Auf der Heide, 1989); Roads, facilities, and facilities intact (Auf der Heide, 1989).	Resources often exceed management capacity (Auf der Heide, 1989); Roads my be blocked or jammed, telephones jammed or not functioning (Auf der Heide, 1989).
Processes	A typical IM cycle covers all the different process phases including detection, verification, warning, respond, driving, arrival, operation (action), normalization and flow recovery (Zwaneveld *et al*., 2000)	A typical DM cycle includes mitigation, preparedness, response, and recovery (Board on Natural Disasters National Research Council 1999; FEMA, 1998).
Type of activities / tasks	Familiar routine tasks and procedures (Auf der Heide, 1989) Everyday, predictable events that people have trained for as incidents (e.g. small fire, robbery, traffic accidents). (Janssen *et al*., 2010).	Unfamiliar tasks and procedures (Auf der Heide, 1989) Once an incident exceeds a certain magnitude, has a broad exposure, exhibits unpredicted events, and cannot be considered a routine accident that can be solved independently by one or several different service organizations, we talk about a disaster (Janssen *et al*., 2010). Complex, ambiguous, and unstable task environments

3. DEVELOPMENTS IN INFORMATION SHARING

3.1 European perspective

Within Disaster Management, the fragmentation of research and development efforts in Europe is most harmful. In 2004, the European Commission developed a new vision on security research (See Directive 2004/590/EC). It addresses the growing and diversifying security challenges. In doing this, Europe needs to reduce fragmentation, duplication of effort, increase cooperation and, achieving standardization and interoperability. Hereby technology plays a key role. Based on the report of the European Security Research Advisory Board (ESRAB, 2006), four security missions have been identified to develop technologies and knowledge for building capabilities to ensure security for the EU citizens. Related to traffic IM, the mission "*Security of infrastructure and utilities*" is the most relevant, but the other three are also (in)directly related. As well as that, there is a special focus on cross-cutting missions for system integration, interconnectivity and interoperability.

From the many European initiatives a nice example is ORCHESTRA. The Open Geospatial Consortium (OGC) has a Risk and Crisis Working Group which liaises with ORCHESTRA to synchronize their work activities. ORCHESTRA is a European Union project, which designs and implements specifications for a service-oriented spatial data infrastructure for improved interoperability among risk management authorities in Europe. The service-oriented spatial data infrastructure will enable the handling of more effective disaster risk reduction strategies and DM operations (www.eu-orchestra.org). Another EU initiative is OASIS (www.oasis-fp6.org). The main objective of this project is to define and develop an information technology framework based on open and flexible standards as a basis of a European DM system designed to support the response to any scale of disaster. In an evaluation report (OASIS, 2006) it is concluded that it is extremely difficult to develop systems to support the whole spectrum of emergency operations. Existing systems should be better linked to OASIS. End-users indicated that information management, access, and exchange, and, improving situational awareness are crucial requirements. Despite all the EU initiatives, there has not yet been a European operational emergency system like the National Incident Management System (NIMS) in the US. However this has still not been implemented everywhere (US Department of Homeland Security, 2008).

A recent White Paper on traffic safety management concludes that the fragmentation of research and development efforts in Europe is most harmful (see Directive 2011/144/EC). Recently, the Conference of European Directors of Roads (CEDR) developed the guideline 'Best Practice in Europe' for traffic IM (CEDR, 2011). The purpose of CEDR is to facilitate cooperation on a European level by exchanging experience and information in order to make progress in the road safety and road transport sector (CEDR, 2008). Another initiative comes from EasyWay, who have created a long-term vision in their '*Strategy and Action Plan*' (EasyWay, 2010), and will implement most parts of the Intelligent Transport Systems (ITS)

action plan (see Directive 2008/886/EC). A new legal framework was adopted to accelerate the deployment of these innovative transport technologies, and is an important instrument for the coordinated implementation necessary to establish interoperable and seamless ITS services (Directive 2010/40/EC). For traffic IM services, the deployment guidelines *Incident Management* and *Incident warning* is the most relevant (EasyWay, 2011). However, on a European level there is still not yet an overall operational incident management system. The currently used IM information systems are developed on a national scale, and have the same kind of problems in terms of system diversity, architecture, and a lack of standards.
'Interoperability' is the ability of diverse systems and organizations to work together. In 2004 the European Commission decided to create an interoperability framework to support the delivery of pan-European eGovernment services for public Administrations, Businesses and Citizens (IDABC: Directive 2004/387/EC). The Interoperable delivery of pan-European eGovernment services to public Administrations, Businesses and Citizens (IDABC) programme provides guidelines to achieve the interoperability of three aspects: technical, semantic and organizational interoperability. Recently, on 31 December 2009, the new ISA (Interoperability Solutions for European Public Administrations) programme was delivered as a European Interoperability Framework (EIF 2.0) and adds a legal level and a political context (ISA, 2009).

3.2 Dutch perspective

Based on different evaluation studies of past disasters, there has been a number of initiatives to improve the cooperation between emergency organizations. Based on the airplane crash in 1992 in Bijlmermeer (Amsterdam), the Dutch government decided to implement a single communication network for the police, the fire brigades and the first medical aid teams (Boersma *et al.*, 2009). C2000 is a digital radio network specially developed to support public safety. An important development in cooperation was the introduction of integrated co-location emergency room which also implies the integration of the police emergency room's ICT content systems;

- multi-disciplinary co-location operators of the three disciplines are housed together, but operators only take discipline-specific calls;
- a virtual co-location the operators are not necessarily housed in one room, but can have face-to-face contact with each other by means of ICT.

Based on this multi-disciplinary approach, the Gemeenschappelijk Meldkamer Systeem (GMS), an integrated emergency reponse room system was developpped. Main goal is to connect different information sources between the police, the fire brigades and medical aid emergency centres. Although, GMS was introduced on a national level, in practice there are many different versions because regional organization could decide for themselves if and how

to implement the system in their organization. Next to that, there are still many emergency organzations who work with their own closed information systems.
In recent years, also a number of field exercises has been held, to train emergency workers with the new information concepts such as netcentric working. Examples of such exercises are: Project Netcentric Experimenten (Rijk, 2008), Voyager (Ven *et al.*, 2008), Eagle One (Riedijk *et al.*, 2008), Warroom TMO (Riedijk *et al.*, 2008) and CEPNIC (Brooijmans, 2010). These field experiments where supported by different netcentric systems such as CEDR and the Landelijk Crisis Management Systeem (LCMS – National Crisis Management System). These systems are specifically developed for DM and are not implemented within Rijkswaterstaat, the responsible authority for the main road network infrastructure. This is mainly caused by the fact that road authorities have no formal role in the Law on safety regions. As seen in Section 4, the importance of infrastructure is crucial in DM. Different evaluation reports of major disasters, such as the Moerdijk fire in 2011, show that there are still major problems in coordinating traffic management and DM tasks. This is mainly caused by the way (legal) organization structures are established and current information systems support these tasks. Within the new RWS policy, they want to focus more on a professional role in DM (PWC, 2011).
From the geo-information sector, GEONOVEM currently works on an information model on homeland security (IMOOV). This provides the definition of information elements (semantic) and the exchange platform (UML and XML), which is basically the implementation of a Service-Oriented Architecture (SOA). Another interesting geo-related development is *Publieke Dienstverlening Op de Kaart* (PDOK[8] – Public Services On the Map). This is an initiative of several organizations to provide different geo-services. This can serve different tasks for DM, traffic IM and traffic management.

4. LEGAL ASPECTS

In sharing information the ownership and origin of the information to be shared is of utmost (legal) importance. For example, a head-end collision on a highway is in itself, in most EU countries, a civil law problem between the (insurance companies of the) drivers of the involved vehicles. The information exchange is then limited to the legal obligations stemming from the insurance policies of both drivers.
When vehicles start blocking the highway at peak hours the congestion can endanger the safe and secure traffic flow, and it then becomes the responsibility of the National Roads Authority (NRA). Then the exchange of information grows from the individual drivers' responsibilities into more general (legal) responsibilities vested with the road authorities. These authorities start informing other road users of the possible impact the incident might have on their journey.

[8] www.pdok.nl

That will certainly be the case when one or more trucks are involved in the accident/incident. In that case the NRA responsibility to allow for a safe and secure traffic flow becomes even more important, because the accident/incident is potentially causing more impact on the traffic flow. When one of the trucks holds a chemical substance in a tank it might become a disaster (or at least warrant a disaster prevention scheme) that will involve all types of different civil authorities. Not to mention the explosion of information that needs to be shared and will erupt from a small disaster, with pollutive chemicals endangering public health and one driver stuck in his truck. The foregoing paragraphs have described a number of events escalating from a simple incident into near disaster. It is obvious that the information flows needed to help resolve each of these events are escalating also.

The origin, or better, the institution from which the information stems also gives it a legal stamp. Imagine the first case (two cars in a head end collision): if the event is reported through a mobile phone in the Netherlands, then this phone call is being picked up by the national police emergency centre[9]. Depending on the information the caller gives resulting from a precise protocol of questions, asked by the responding officer, (s)he will probably warn the Regional NRA to check whether they can also see the incident. Then it is most probable that the police will leave the resolution of the incident to the traffic management centre and the RWS road inspector. If the same incident is seen from a traffic management camera of the NRA, the police will not even know about the incident of the head-end collision.

There are potentially three more ways of reporting an incident: 1) telephone warning of the local police by a separate telephone number; 2) through telephone warning by road users to the traffic management centre; or 3) through physical report by the RWS road inspector. If it is a bigger incident, or even GRIP-2 for example, the way of reporting stays the same, although many more phone calls might be made by road users and bystanders when a truck is burning on the highway. We need this extensive description of the origin of the (reporting) call, because the institutional and legal system differs when (reported by civilians) information stems from the police emergency room or when it comes straight from the RWS road inspector, and then needs to be shared immediately with other responsible public agencies. RWS is responsible for three networks: water, nautical (ships), and national roads. [10] The police are responsible for detecting, maintaining order, and helping people in distress (Police law, 1993). [11]

Highways are owned by the State and when cars damage safety rails or traffic signs, reimbursement can be required from the car driver who caused the damage on the basis of civil responsibility. Highways are managed by RWS and NRA, under the Act: the

[9] Very instructive to see which protocol needs to be used in case an incident is being reported, see Appendix 4 in http://www.incidentmanagement.nl/Portals/0/Documenten/Incident%20Management%20Handboek.pdf, consulted on August 28, 2012.
[10] See in English http://www.rijkswaterstaat.nl/en/about_us/ , consulted on August 28, 2012.
[11] See for a general account of Policing in the Netherlands, http://www.politie.nl/ImagesLandelijk/politie%20in%20nederland%20engels_tcm31-85725.pdf, consulted August 22, 2012.

Rijkswaterstaatsworks Management Act (1996), upon which the Incident Management Policies Rules are based. It is in these very detailed role descriptions that the diverse emergency services are instructed how to behave on the public highway in case of incidents.

As an example of this, the list of priorities is very instructive: 1) the safety of the emergency workers; 2) traffic safety; 3) treatment of casualties; 4) maintaining the traffic flow; 5) vehicle/cargo salvaging.[12] If the incident is bigger, e.g. GRIP-2 and higher, the legal role of the parties involved in remedying the (small) crisis is different. The flasher services and civil authorities roles are defined in the Law of the Safety regions. This is an Act that defines the relationship between, on the one hand, the emergency services, and on the other, the civil. It also defines how information sharing, considered essential between the involved emergency services and authorities, should be based upon regional plans conceiving on how to operate in case of emergency or crisis. It is in this cooperative structure that the traffic managers are considered to be cooperating partners in how to manage traffic.

Traffic management is the principal responsibility of RWS on the highways. Traffic management during a (defined) crisis is the principal responsibility of the police, but RWS is 'allowed' or asked to deliver input from their knowledge and point of view in case of managing traffic. It is strange that, because the police in the Netherlands no longer wanted a traffic management role on the highways (they 'handed this over to RWS'), but still has a officially traffic management role according to the law when the incident is no longer called an incident but a crisis, and then Rijkswaterstaat's role is no longer 'appreciated' and even kept out of the loop when the responsibilities stemming from the Law on the Safety regions come into play. As a consequence, RWS, because of its legal responsibilities concerning its traffic management task, is considered, through a deal with the police, as the main responsible party on the highways, but it loses its principal role when the incident is no longer an incident, but a GRIP-2 crisis/incident or higher. Then the police are in charge of the 'steering wheel' and decide what to do concerning traffic management. This might be a good and reasonable point of departure with regard to the underlying secondary road network and the local roads, but it does not always make sense in the case of the national highways.

5. PROBLEMS IN INFORMATION SHARING

Informed decisions are a prerequisite for the formulation of successful strategies. To a large extent, however, successful strategies depend on the availability of accurate information presented in an appropriate and timely manner (Grothe *et al*., 2005). The problem with today's information systems is not their lack of information, but the difficulty to find or display the right information when it is needed. Information sharing between different IM/DM organizations is still in its early stages of development. Various studies have concluded that information quality and system quality are still major hurdles for efficient and

[12] Incident Management: The Roles of the Emergency Services in Incident Management in the Netherlands. VCNL, April 2005 ISBN 90-369-0097-2

effective multi-agency emergency services, and are crucial for the success of information systems (Lee *et al.*, 2010). Different evaluation reports, such as the fire in the Schiphol retention complex (Vollehove *et al.*, 2006), the crash of a Turkish Airline Boeing near Schiphol Amsterdam (IOOV, 2009) and the chemical fire incident in Moerdijk (Ministerie van Veiligheid en Justitie, 2011), have revealed that poor information quality hampered the efficiency and effectiveness of interagency disaster response activities.

Information technology is essential to improve information sharing and decision making for emergency responders (Graves, 2004), and it has already drastically reshaped the way organizations interact with each other (Lee and Whang, 2000). Interagency exchange of information is the key to obtain the most rapid, efficient, and appropriate response to highway incidents from all agencies. In current research, there are some general principles that are the basis of successful emergency response information systems (see Turoff *et al*., 2004). In the latter study, the authors describe 12 fundamental roles that should be supported by an DM system. In many studies, problems related to information sharing, communication, and coordination have been identified as the main bottlenecks for effective cooperation between emergency services (e.g. Comfort *et al.,* 2004; Chen *et al.*, 2008).

5.1 Disaster management

5.1.1 Information needs

Information plays a crucial role for effective DM. ACIR (2005) made a distinction between semi-static, dynamic, and model information. They cluster the relevant information components to support large-scale emergencies (disasters) into 8 different categories (see Figure 3).

The report *Basisvereisten Crisis Mangement* (In English: Basic constraints Crisis Management) (2006), and Article 2.4.1 under the section on information management *Besluit veiligheidsregio's* (in English, Decision on Safety regions) (2010), contains an extensive overview of which information at least needs to be integrated in a Common Operational Picture (COP). Based on Homeland (2008): "*A COP is established and maintained by gathering, collating, synthesizing, and disseminating incident information to all appropriate parties*". Focussing on cooperation and multi-services: "*Achieving a COP allows on-scene and off-scene personnel to have the same information about the incident, including the availability and location of resources and the status of assistance requests.*" It contains information about the incident, the emergency aid, the prognosis and emergency activities, the specific measures, and their results (effects).

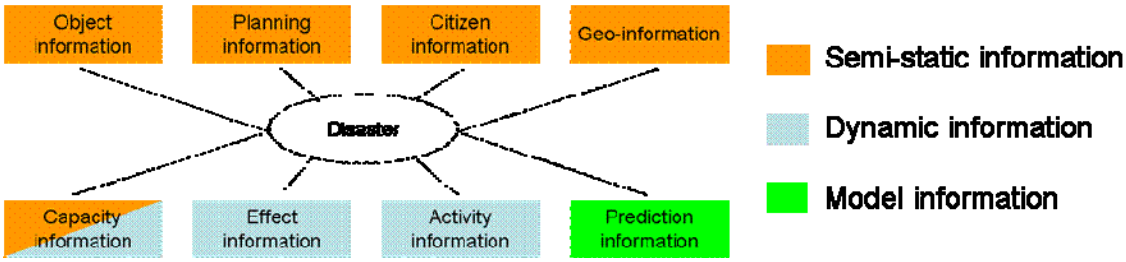

Figure 3: Overview of information categories which need to be available in the case of large-scale disasters.
Source: ACIR (2005).

5.1.2 Problems

In the Netherlands, the main identified information problems can be grouped in two main categories: 1) Having information, the availability and accessibility of correct and complete information for effective execution of emergency tasks and decision making, and, 2) sharing information between involved emergency services (ACIR, 2005).

Table 6: identified information problems (ACIR, 2005)

	Identified problems
Have information	• some necessary information is not available; • many needed information is not (fast) accessible; • part of the information is not usefull; • necessary information is structural collected insufficient • part of the information is interpreted insufficient.

Share information	• information is unsufficient shared:
	  • with other disciplines;
	  • with other regions;
	  • within the hierarchical organization;
	  • between ministries;
	  • with newsmedia and citizens.
	• insufficiënt communication and coordination.

Other European studies on emergency response plans for floods (e.g. Lumbroso *et al.*, 2011, 2012; Lumbrose and Vinet, 2011, 2012), concluded that they needed more information and a better understanding of the hazard, and the possible consequences; and it recommended improving emergency planning with better information sharing and engagement. Good crisis communication, planning, and delivery can reduce the impact and effects of a crisis. Hale *et al.* (2005) identified the main information and communication problems during crisis respons. Passenier *et al.* (2012) assess the usability of public inquiry report data to build a formal trace that can be used to create an agent model simulating crisis response coordination. It provides an taxonomy of the main identified data problems: coordination practices, communications networks, situational properties, and information systems and communication system.

5.2 Traffic incident management

5.2.1 Information needs

It is important to notice that almost all information has a spatial (geographical) component. To improve situational awareness, road organizations need to have real-time access to different kinds of information such as:

- Alerts - Has something happened?
- Location - Where is congestion located? Where are the road users? Where are the incident managers / emergency services?
- Flows - Where is the traffic moving?
- Cause - What causes congestion: incidents, events, weather?
- Numbers - How many people are involved?
- Movement - Is the incident stationary or in movement?
- Mobility - How far do the consequences of an incident reverberate on the road network? What is the site accessibility of the emergency services?
- Safety - What risks are there for the surrounding areas (e.g. chemical spills)?
- Security - Which systems can provide real information about the vicinity of large incidents?
- Command and Control - How should we respond? What traffic management strategies do incident managers have at their disposal?
- Prediction - How can we anticipate the incident? Are there special events with a higher risk of traffic jams and possible incidents?

Information needs for traffic IM can be grouped in three main categories: incident, surrounding environment, and organization intelligence (Steenbruggen *et al.*, 2012c). Identified problems in information, communication and coordination can be related to these information categories.

5.2.2 Problems

Information systems play an important role in carrying out daily IM activities. Interagency exchange of information is the key to obtaining the most rapid, efficient, and appropriate response to highway incidents from all agencies. Public safety agencies and transportation organizations often have information that is valuable for each other's operations. For example, better incident detection and notification, road situation information, incident site status and coordination information (US NCHRP, 2004). Cooperation between emergency services, in terms of information sharing, communication, and coordination is becoming increasingly important to apply traffic IM successfully. The emergency services have traditionally been alerted and have shared information via traditional landline and mobile phone calls. Historically, each organization has developed information systems which are primarily designed as closed systems which mainly support their own specific IM tasks. Even within organizations there are still many problems in terms of system diversity, architecture, and standards used. However, organizations are starting to realize that introducing new interoperable system concepts forms an important constraint for significantly improving cooperation.

6. NEW INFORMATION CONCEPTS

The evolution of computing and communication technologies have always represented a source of innovation for DM, which has adopted digital technologies at the core of the discipline and evolved in terms of the availability of better and more sophisticated tools (see, for instance, Perry and Doerfel, 2003; Turoff *et al.*, 2004, Zlatanova and Li, 2008). Some emerging technology trends, however, have both a close affinity to the discipline and the potential to create radical disruptions and innovation in the way DM evolves.

Multi-agency DM requires collaboration among geographically distributed public and private organizations to enable a rapid and effective response to an unexpected event. In recent years there has been a growing interest in the use of 'netcentric' information concepts to improve the cooperation between different organizations with a common goal. The main goal of netcentric operations is to improve the Situational Awareness (SA) which can be achieved by a Common Operational Picture. Most simply, SA has been generally defined as "*knowing what is going on around you*" (Adam, 1993; Adams *et al.*, 1995; Endsley and Garland, 2000). Although the term 'Situational Awareness' itself is fairly recent, the evolution and adoption of the concept has a long history, as described by Harrald and Jefferson (2007). The concept of SA finds its roots in the long history of military theory in combination with netcentric information concepts (Alberts *et al.*, 2000, 2001; Alberts, 2002). Most of the related research was originally conducted in the field of military aviation safety in the mid-1980s in order to design computer interfaces for human operators (Endsley, 1988; Dominguez *et al.*, 1994; Endsley, 1995). In the literature, a number of different definitions and concepts of Netcentric Operations can be found: Network Enabled Capabilities – NEC (UK); Ubiquitous Command and Control – UC2 (AUS); Network Based Defence – NBD (Sweden); and Net-Centric Operations – NCO (US and NATO). A few years later, the term NEC was also used by other government agencies in papers on DM and homeland security (Boyd *et al*., 2005).

In the Appendix of the *Besluit Veiligheidsregio* (in English Decision of Safety regions, 2010), it is explicitly stated that new implemented information services to support large scale disasters need to be based on netcentric operations. In the report *Referentie kader Regionaal Crisisplan* (Reference Framework Regional Crisis Plan, 2009), guidelines are provided to help safety regions to formulate crisis plans, which contain a specific section on netcentric operations.

In Harrald and Jefferson (2007), it is stated that "*The transfer of the concepts COP, SA and netcentric working from their safety and combat origins to the complex, heterogeneous emergency management structure will be exceedingly difficult, and that short term strategies based on the assumption that shared situational awareness will be easily achieved are doomed to failure.*"

In contrast to the wealth of literature on information systems success in profit-oriented business environments, research regarding drivers of public sector IS success is scarce or non existent (Lee *et al.*, 2010). Since 2005, several regions in the Netherlands have made efforts to implement a network approach. This led to a number of evaluation studies from different research perspectives. From a communication perspective to improve the decision-making process, van de Ven *et al.* (2008) concluded that the real benefit of NCO will be realized only if the training of people to work in a network is implemented. In a related study, Schraagen and van de Ven (2008) identified a number of requirements that are essential for support systems that intend to eliminate tunnel vision and alleviate communication and coordination problems in crisis response organizations. Treurniet et al. (2012) stated that a COP and shared SA are essential but not sufficient for effective collaboration. Based on Hayes (2007), they stated that understanding a certain level of shared collaboration awareness is required as well. This is also called organization awareness (see Oomes, 2004). This should support coordination, which is the synchronization of work processes (Okhuysen and Bechky, 2009), in the cooperation between emergency organizations. Treurniet *et al.* (2012) defined three conditions for collaboration awareness: Accountability, predictability, and common understanding.

Bharosa *et al.* (2010) looked at the relation between information sharing and coordination by observing and surveying disaster response exercises. They identified a large number of obstacles and challenges based on literature research, field observations, and a survey. They conclude that there is no single factor that impedes or facilitates information sharing and coordination. Information sharing and coordination are influenced by obstacles located within and between the community, agency and individual levels. All three levels contain institutional and technological elements. Solving problems at one particular level only is unlikely to improve information sharing and coordination. The performance of multi-agency DM will improve when, and only when, the relevant obstacles are dealt with simultaneously at the various levels

Almost all necessary information to support DM have a geo-graphical location component. From a geo-perspective, there has been a number of initiatives to adopt geo-information communication technology (e.g. Kevany, 2003; Cova, 2005; Zlatanova et al., 2006; Parker *et al.*, 2007; Grothe *et al.*, 2008; Zlatanova and Li, 2008) and, NEC/NCW concepts for DM and homeland security (e.g. Brooijmans *et al*., 2008; Neuvel *et al.*, 2010). Brooijmans *et al.* (2008) conclude that the technology side, standards, and Spatial Data Infrastructures (SDI) / Geospatial Data Infrastructures (GDI) for DM are well described. One of the underpinning concepts of a GDI is that its implementation must be user-driven. Neuvel *et al.* (2010), developed an evaluation method that is able to measure the improvement that the use of geo-information has on DM.

Janssen *et al.* (2010) concluded that many DM systems often lack the capability to cope with the complexity and uncertainty. Their paper concludes that although there is a common body of knowledge, DM is still an under-developed area. There is a need to relate practice and theory by using human-centred approaches such that DM can realize its full potential. In particular, the role of information, enterprise architecture, coordination and related human efforts are aimed at improving multi-agency DM.

Lee *et al.* (2010) examine and extend the theory of information systems success in the context of large-scale DM for public safety. In the recent past, various evaluation reports on DM efforts have concluded that information and system quality are major hurdles for efficient and effective multi-agency DM, and are critical antecedents for information systems (IS) success (see e.a. Strong *et al.* 1997; Perry *et al.* 2004; Singh *et al.*, 2009; Bharosa *et al.*, 2009). Bharosa (2011) analyses different pathways to show how NCO theory can assure higher information and system quality. The main aim is to contribute design principles that can assure a higher information quality and system quality for relief workers in public safety networks. A pathway is a specific progression of one or more concepts in the evolution of the theory. This approach is called the design theory *netcentric information orchestra*, since it draws upon the pathways of netcentricity and IT enabled orchestra. Information management, including the tasks of collecting, distributing, processing, and presenting disaster related information, is essential for the coordination of disaster response activities (Ryoo and Choi, 2006). In Bharosa *et al.* (2011), they defined the capabilities which are needed for assuring information quality in public safety networks. From an ethnographic approach, Boersma *et al.* (2009) studied different aspects of information sharing and cooperation in a safety region. They showed that the establishment of safety regions, the co-location of emergency response rooms, and the implementation of new ICTs had a major impact on cooperation. The study clearly shows that insufficient information management and complex organizational configurations are the main bottlenecks.

A recent report (U.S. Department of Transportation, 2009) focuses on information needs, issues, and barriers to information sharing between public and private IM organisations. However, they do not include new information concepts such as NCW, COP and SA. Steenbruggen *et al.* (2012c) give an extensive overview how these concepts can be applied to traffic IM to improve cooperation between public and private organizations.

7. DISCUSSIONS

The Netherlands is by far one of the safest countries in the world. However, the relatively small number of large scale disasters and daily traffic accidents have a huge impact on society. In the Netherlands, for example, traffic accidents and delays are estimated to cost

€10.4-13.6B/year of which delays alone cost €2.8-3.6B/year. Delays attributable to incidents amounts to 12 per cent of this, ie €336-432M/year. Traffic injuries are a major public health issue. In 2010 there where 640 fatal casualties and approximately 17,000 injured. For example in the EU, in 2011 there were around 30,500 people lost their lives in traffic incidents on the EU road network, while around 1.5 million were injured, at huge economic and human cost to society[13]. That makes the Netherlands the fourth safest country in the EU per million inhabitants (European Transport Safety Council, 2011). Another way to measure safety is to take into account the distance travelled by the inhabitants.

In the many evaluation studies, information, communication, and coordination are identified as the main problems of an effective cooperation between emergency services. There are some significant differences between DM and traffic IM in terms of definitions, goals, type of events, organization, communication, coordination, resources, workprocesses and activities. Traffic IM can be seen as a special case of simplified DM. They both have a strong relation with traffic management in case of a disaster or traffic incident. There is relative a wealth of literature and empirical studies on DM. However, literature on traffic IM, and especially information services, is scarse and almost non-existent. DM struggles already for many years to adopt netcentric working. As stated by Harrald and Jefferson (2007): "*The transfer of the concepts will be exceedingly difficult, and that short term strategies are doomed to failure*". Therefore, gouverments and private actors should collaborate more in terms of field exercises and related studies. Especially, because the involved emergency organzations (Police, Fire Brigade, Ambulance services, and road authorities) have a large overlap in the two domains. It is crucial that organizations are aware of each others roles and formal tasks. Especially the role of Traffic Management (TM) is not well defined within DM.

Despite efforts towards European harmonization, there is still considerable variety of IM, TM and DM deployment across Europe, with a lack of uniform architecture, standards, data models, and definitions, and there is no general agreement on the different process phases; Solutions for interoperable information systems for traffic IM need to balance between standards in traffic management, disaster management en the geo-information sector.

A European IM interoperable framework should at least address four specific goals: cross-border management between countries; support different escalation levels of crisis management; support information-sharing between public and private emergency services and road authorities, and a uniform IM application should be applied on the TERN infrastructure. A joint European introduction of net-centric information systems could be an enabler to support these goals. However, further research in absolutely necessary. Finally, traffic IM could be a stable environment to introduce the netcentric approach. DM organizations, who have a large overlap, with traffic IM, could get routine experience by the large number of

[13] http://ec.europa.eu/transport/road_safety/specialist/statistics/trends/index_en.htm

daily traffic incidents. This could help to overcome the problems as currently being identified in literature.

References

References from Journals and conferences:

Adam, E.C. (1993). Fighter cockpits of the future. Proceedings of 12th IEEE/AIAA Digital Avionics Systems Conference (DASC), pp. 318-323.

Adams, M., Tenney, Y. and Pew, R. (1995). Situation awareness and the cognitive management of complex systems. *Human Factors* 37(1), pp. 85-104.

Bharosa, N., Zanten, B. van, Zuurmond, A. and Appelman, J. (2009). Identifying and confirming information and system quality requirements for multi-agency disaster management, in: *Proceedings of the 6th International Conference on Information Systems for Crisis Response and Management (ISCRAM)*, J. Landgren, U. Nulden & B. van de Walle (Eds.).

Bharosa N., Lee, J. and Janssen, M. (2010). Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises. *Information Systems Frontiers* 12(1), pp. 49-65.

Bharosa, N. (2011). Netcentric Information Orchestration, Assuring information and system quality in public safety networks, Dissertation, Technische Universiteit Delft, 2011, ISBN 978-90-8891-231-3.

Bharosa, N., Janssen, M. and Tan, Y-H. (2011). A research agenda for information quality assurance in public safety networks: information orchestration as the middle ground between hierarchical and netcentric approaches. *Cogn Tech Work* 13, pp. 203-216. DOI 10.1007/s10111-011-0172-9.

Board on Natural Disasters National Research Council (1999). Mitigation emerges as a major strategy for reducing losses caused by natural disasters. Science, 284(5422), pp. 1943-1947. doi:10.1126/science.284.5422.1943.

Boersma, K., Groenewegen, P. and Wagenaar, P. (2009). Emergency Response Rooms in Action: an ethnographic case-study in Amsterdam, in: *Proceedings of the 6th International ISCRAM Conference,* J. Landgren & S. Jul (Eds.), Gothenburg, Sweden, May 2009.

Brooijmans, P., Riedijk, A., Jacobs, C., Lassche, R. and Scholten, H.J. (2008). Measurement of the added value of geographic information in disaster management, in: *Proceedings of the 11th GDSI conference*, Rotterdam, the Netherlands, 2009. VU University Amsterdam, Spatial Information Laboratory, The Netherlands,

Chen, R., Sharman, R., Rao, R., and Upadhyaya, S. (2008). Coordination in emergency response management. *Communications of the ACM*, 51(5), pp. 66-73. doi:10.1145/1342327.1342340.

Comfort, L. and Kapucu, N. (2006). Inter-organizational coordination in extreme events: The World Trade Center attacks, September 11, 2001. Natural Hazards, 39(2), 309–327. doi:10.1007/s11069-006-0030-x.

Comfort, L., Ko, K. and Zagorecki, A. (2004). Coordination in rapidly evolving disaster response systems: the role of information. *The American Behavioral Scientist*, 48(3), pp. 295-313. doi:10.1177/0002764204268987.

Cova, T.J. (2005). GIS in emergency management. In P.A. Longley, M.F. Goodchild, D.J. Maguire, & D.W. Rhind (Eds), Geographical information systems: Principles, techniques, management, and applications (2nd ed., pp. 845-858). New York: Wiley.

Duke, S. and Masland, L. (2002). Crisis Communication by the Book. *Public Relations Quarterly*, 47(3), pp. 30-36.

Endsley, M.R. (1988). Design and evaluation for situation awareness enhancement. In Proceedings of the Human Factors Society 32nd Annual Meeting (pp. 97-101). Human Factors Society, Santa Monica, CA.

Endsley, M.R. (1995). Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors* 37(1), pp. 32-64.
Faraj, S. and Xiao, Y. (2006). Coordination in fast-reponse organizations. *Management Science* 52(8), pp. 1155-1169.
Green W.G. III and McGinnis S.R. (2002), Thoughts on the higher order taxonomy of disasters, in: *Notes on the Science of Extreme Situations*, Paper No. 7.
Graves, R. (2004). Key technologies for emergency response. Paper presented at the First International Workshop on Information Systems for Crisis Response and Management ISCRAM2004, Brussels.
Hale, J.E., Dulek, R.E. and Hale, D.P. (2005). Crisis Response Communication Challenges: Building Theory from Qualitative Data, *Journal of Business Communications* 42(2), pp. 112-134.
Harrald, J. and Jefferson, T. (2007). Shared Situational Awareness in Emergency Management Mitigation and Response, in: *Proceedings of the 40th Hawaii International Conference on System Sciences*, 1530-1605/07, 2007 IEEE.
Hayes, R.E. (2007). It's an endeavor, not a force. *The International C2 Journal (Special issue: The future of C2).* 1(1), pp 145-176.
Janssen, M., Lee, J., Bharosa, N. and Cresswell, A. (2010). Advances in multi-agency disaster management: Key elements in disaster research. *Inf Syst Front* 12, pp. 1-7.
Kapucu, N. (2006). Interagency communication networks during emergencies: Boundary spanners in multiagency coordination. *American Review of Public Administration* 36(2), pp. 207-225. doi:10.1177/0275074005280605.
Kevany, M.J. (2003). GIS in the World Trade Center attack-trial by fire. *Computers, Environment and Urban Systems*, 27(6), pp. 571-583.
Lee, H.L. and Whang, S. (2000). Information sharing in a supply chain. *International Journal of Technology Management*, 20(3), pp. 373-387. doi:10.1504/IJTM.2000.002867.
Lee, J., Bharosa, N., Yang. J., Janssen, M. and Rao, H.R. (2010). Group value and intention to use - A study of multi-agency disaster management information systems for public safety. Decis. Support Syst. (2010), pp. 1-11. doi:10.1016/j.dss.2010.10.002.
Lerbinger, O. (1997). The crisis manager: Facing risk and responsibility. Mahwah, NJ: Erlbaum. Min, Seung-Ki; Xuebin Zhang; Francis W. Zwiers; Gabriele C. Hegerl (2011). Human contribution to more-intense precipitation extremes, *Nature* 470, pp. 378-381.
Lumbroso, D.M., Stone, K. and Vinet, F. (2011) An assessment of flood emergency plans in England and Wales, France and the Netherlands, *Natural Hazards* 58(1), July 2011 , pp. 341-363.
Lumbroso, D.M., Mauro, M. Di., Tagg, A.F., Vinet, F. and Stone, K. (2012). FIM FRAME: A method for assessing and improving emergency plans for floods. *Journal of Natural Hazards and Earth System Sciences* 12, pp1731-1746, 2012.
Lumbroso, D.M. and Vinet, F. (2011). A comparison of the causes, effects and aftermaths of the coastal flooding of England in 1953 and France in 2010, *Natural Hazards and Earth System Sciences* 11, pp. 2321-2333, 2011, doi:10.5194/nhess-11-2321-2011.
Lumbroso, D.M. and Vinet, F. (2012). Tools to improve the production of emergency plans for floods – are they being used by the people that need them? *Journal of Contingencies & Crisis Management* DOI: 10.1111/j.1468-5973.2012.00665.x.
Mendonca, D. (2007). Decision support for improvisation in response to extreme events: learning from the response to the 2001 World Trade Center attack. *Decision Support Systems* 43(3), pp. 952-967. doi:10.1016/j.dss.2005.05.025.
Neuvel, J.M.M., Scholten, H.J. and Brink, A. van den (2010). From Spatial Data to Synchronised Actions: The Network-centric Organisation of Spatial Decision Support

for Risk and Emergency Management, *Appl. Spatial Analysis*, 2010, DOI 10.1007/s12061-010-9059-z.

Okhuysen, G.A. and Bechky, B.A. (2009). Coordination in Organizations: An Integrative Perspective, *The Academy of Management Annals* 3(1), pp. 463-502.

Oomes, A.H. J. (2004). Organization Awareness in crisis management, Dynamic organigrams for more effective disaster management, in: *Proceedings of ISCRAM 2004*, B. Carle & B. van de Walle (Eds.), pp. 63-68.

Perry, D.C., Taylor, M., and Doerfel, M. (2003). Internet based communication in crisis management. *Management Communication Quarterly* 17, pp. 206-233.

Ryoo, J. and Choi, Y.B. (2006). A comparison and classification framework for disaster information management systems. *International Journal of Emergency Management*, 3(4), pp 264-279.

Schraagen, J.M. and Ven, J.G.M van de (2008). Improving Decision Making in Crisis Response Through Critical Thinking Support. *Journal of Cognitive Engineering and Decision Making* 2(4), Winter 2008, pp. 311-327. DOI 10.1518/155534308X377801.

Steenbruggen, J., van der Vlist, M. and Nijkamp, P. (2012a). Traffic Incident Management in a Digital Society - Challenges and obstacles in information technology use in urban Europe. *TF&SC*, Special issue 'Upgrading the City via Technology', forthcoming.

Steenbruggen, J., Kusters, M. and Broekhuizen, G. (2012b). Best practices in European traffic Incident Management, in: *Proceedings Transport Research Arena Conference, Social and Behavioral Sciences* 48, pp. 297-310. Athens, Greece, 23-26 April 2012.

Steenbruggen, J., Nijkamp, P., Smits, J. and Grothe, M. (2012c). Traffic Incident Management, A Common Operational Picture to support Situational Awareness of Sustainable Mobility, *International Journal of Transport Economics* Vol. XXXIX, No.1, pp. 131-170. March 2012.

Strong, D.M., Lee, Y.W., and Wang, R.Y. (1997). Data quality on context. *Communication of the ACM* 40(5), pp. 103-110.

Treurniet, W., van Buul-Besseling, K. and Wolbers, J.J. (2012). Collaboration awareness - a necessity in crisis response coordination, in: *Proceedings of the 9th International ISCRAM Conference*, Vancouver, Canada, April 2012, L. Rothkrantz, J. Ristvej & Z. Franco (Eds.).

Turoff, M. Chumer, Walle, B. van de, and Yao, X. (2004). The Design of a Dynamic Emergency Response Management Information System (DERMIS), *The Journal of Information Technology Theory and Application (JITTA)* 5(4), pp. 1-35.

Ven, J. van de, Rijk, R. van, Essens, P. and Frinking, E. (2008). Network Centric Operations in Crisis Management, in: *Proceedings of the 5th International ISCRAM Conference*, Washington, DC, USA, May 2008. pp. 764-773, F. Fiedrich & B. Van de Walle (Eds.).

Zlatanova, S , Oosterom, P.J.M. van and Verbree, E. (2006). Geo-information support in management of urban disasters. *Open House International*, 31(1), pp. 62-69.

References from Books:

Endsley, M. R. and Garland, D. G. (2000). *Situation Awareness, Analysis and Measurement*, Lawrence Erlbaum Associates, Publishers, Mahway, New Jersey.

Grothe, M.J.M., Landa, H.C. and Steenbruggen, J.G.M. (2005). The Value of Gi4DM for Transport and Water Management, in: Geo-information for Disaster Management, P. van Oosterom and E.M. Fendle (Eds.), ISBN 3-540-24988-5. Springer Berlin Heidelberg, New York.

Grothe, M.J.M., Landa, H.C. and Steenbruggen, J.G.M. (2008). The value of GDI4DM for transport and water management, in: S. Zlatanova & J. Li (Eds.), *Geospatial Information Technology for Emergency Response. ISPRS Book Series*, Routledge, 2008.

Passenier, D., Molle, J., Wolbers, J., Boersma, K. and Groenewegen, P. (2012). Formalization of Crisis Response Coordination, in: *Proceedings of the 9th International ISCRAM Conference*, L. Rothkrantz, J. Ristvej & Z. Franco (Eds.).Vancouver, Canada, April 2012.

Perry, W., Signori, D. and Boon, J. (2004). Exploring Information Superiority: A Methodology for Measuring the Quality of Information and its Impact on Shared Awareness. The RAND Corporation. Santa Monica, CA. ISBN 0-8330-3489-8.

Parker, C.J., MacFarlane, R. and Philips, C. (2007). Integrated emergency management: experiences and challenges of a national GI provider, Ordnance Survey. In S. Zlatanova & J. Li (Eds.), GI-technology for emergency response (pp. 275–312). London: Taylor & Francis.

Singh, P., Singh, P., Park, I., Lee, J., and Rao H.R. (2009). Information Sharing: A study of information attributes and their relative significance during catastrophic events. Cyber-Security and Global Information Assurance: Threat Analysis and Response Solutions, K.J. Knapp (Eds.), IGI Global.

Wagenaar, P., F.K. Boersma, P. Groenewegen and P. Niemantsverdriet (2009). 'Coping with 'colocation' Implementing C2000 and GMS in the Dutch police region 'Hollands-Midden', in: Meijer, A., F.K. Boersma and P. Wagenaar, ICTs, Citizens & Governance: After the Hype! IOS Press, Amsterdam, pp. 119-134.

Zlatanova, S. and Li, J. (2008). Geospatial Information Technology for Emergency Response, Taylor & Francis.

References from other Literature:

ACIR (2005). The Laxity Beyond. Towards an effective multidisciplinary information provision from large-scale joint action in our decentralized unitary state. In Dutch: De Vrijblijvendheid Voorbij. Op naar een effectieve multidisciplinaire informatievoorziening bij grootschalig gezamenlijk optreden in onze gedecentraliseerde eenheidsstaat.

Alberts, D. S., Garstka, J. J. and Stein, F. P. (2000). Network Centric Warfare. Developing and Leveraging Information Superiority. CCRP Publication Services, Washington, pp 287.

Alberts, D. S., Garstka, J. J., Hayes, R. E. and Signori, D. A. (2001). Understanding Information Age Warfare. CCRP Publication Services, Washington, pp. 319.

Alberts, D. S. (2002). Information Age Transformation. Getting to a 21st Century military. CCRP Publication Services, Washington, pp. 155, First published 1996.

Auf der Heide, E. (1989). Disaster Response: Principles of Preparation and Coordination. Toronto, C.V. Mosby Company.

Basis vereisten crisis management (2006). (In English: Basic constraints Crisis Mangement). Landelijk Beraad Crisisbeheersing, De decentrale normen benoemd, Den Haag, november 2006.

Besluit veiligheidsregio (2010). Besluit van 24 juni 2010, houdende regels inzake de organisatie en de taken van de veiligheidsregio's en de gemeentelijke brandweer, alsmede de financiële bijdrage van het Rijk (Besluit veiligheidsregio's), Staatsblad van het Koninkrijk der Nederlanden, Jaargang 2010, nr. 255.

Boyd, C., Williams, W., Skinner, D. and Wilson, S. (2005). A comparison of approaches to assessing Network-Centric Warfare (NCW) concept implementation, Systems Engineering / Test and Evaluation (SETE 2005) conference, http ://www.concepts.aero/documents/SETE-2005-NPI.pdf (last accessed 12-01-2011).

Brooijmans, P. (2010). Rapport Real-time informatie stromen. IVENT A&A CDC, 22 december 2010.

BZK (2009). Nationaal Handboek Crisisbesluitvorming. Ministerie Binnenlandse zaken.
Conference of European Directors of Roads (CEDR) (2008). Strategic Plan 2009-2013. Submitted by: Strategic plan ad-hoc group, 7 October 2008.
Conference of European Directors of Roads (CEDR) (2011). Best Practice in European Traffic Incident Management. Final Report of Task 13, March 2011.
Dominguez, C., Vidulich, M., Vogel, E. and McMillan, G. (1994). Situation awareness: Papers and annotated bibliography. Armstrong Laboratory, Human System Center, ref. AL/CF-TR-1994-0085.
Dutch Firebrigade law (1985). see: http://www.st-ab.nl/wetten/0052_Brandweerwet_1985.htm
Dutch Police law (1993). see: http://www.politie.nl/ImagesLandelijk/politie%20in%20nederland%20engels_tcm31-85725.pdf
Dutch Ministry of Transportation and Water Management (1999). Policy rules Incident Management Rijkswaterstaat Netherlands.
Dutch Ministry of Transportation and Water Management (2004). Red blue booklet, the roles of Emergency services in Incident Management in the Netherlands. ISBN 90-369-0097-2 April 2005.
Dutch Ministry of Transportation and Water Management (2008). Strategische plan Verkeersveiligheid 2008 – 2020. Van, voor en door iedereen. Mei 2008.
Dutch Ministry of Transportation and Water Management (2010). Kerncijfers Verkeersveiligheid.
EasyWay (2010). Strategy and Action Plan 2010 - 2020. The policy framework Core European ITS Services and Actions.
EasyWay (2011). Traffic Management Services, Guidelines for the deployment of Incident Warning and Management. Core European ITS Services and Actions, TMS-DG05-08, Draft version 0.9, September, 2011.
European Commission, EU Directive 2001/370/EC. European transport policy for 2010: time to decide, Brussels, 12.9.2001.
European Commission, EU Directive 2004/287/EC. Interoperable delivery of pan-European eGovernment services to public administrations, businesses and citizens (IDABC), Brussels, 21 April 2004.
European Commission, EU Directive 2004/590/EC. Security Research: The Next Steps, Brussels, 7.11.2004.
European Commision, EU Directive 2008/886/EC. Action Plan for the Deployment of Intelligent Transport Systems (ITS) in Europe, Brussels, 16.12.2008.
European Commision, EU Directive 2010/40/EC. Framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, Brussels, 7 July 2010
European Commission, EU Directive 2011/144/EC. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, Brussels, 28.3.2011.
European Security Research Advisary Board - ESRAB (2006). Meeting the challenge: the European Security research Agenda. ISBN 92-79-01709-8. September 2006.
European Transport Safety Council (2011). 2010 Road Safety Target Outcome: 100,000 fewer deaths since 2001. 5th Road Safety PIN Report.
Federal Emergency Management Agency (FEMA) (1998). Introduction to Mitigation Independent Study Course. IS 393. USA, 1998.
GRIP (2006). Referentiekader opschaling (GRIP). Circulaire Ministerie BZK, 11 september 2006.

Homeland Security (2008). National Incident Management System, December 2008.
Interoperability Solutions for European Public Administrations – ISA (2009). European Interoperability Framework (EIF) draft version 2.0.
IOOV (2009) Poldercrash 25 februari 2009. Een onderzoek door de Inspectie Openbare Orde en Veiligheid, insamenwerking met de Inspectie voor de Gezondheidszorg. Den Haag: Ministerie Binnenlandse Zaken en Koninkrijksrelaties (in Dutch).
Koene, J., Mannering, F.L. and Hallenbeck, M.E. (1991). Framework for developing incident management system, Washington State Transportation Center, August 1991.
Law on quality improvement of Dutch Disaster Management (2004). Wet kwaliteitsbevordering rampenbestrijding. Staatsblad 2004, nr. 184, 13 april 2004.
Law on Dutch Safety Regions (2010). Wet veiligheidsregio's. Staatsblad 2010, nr. 145, 11 februari 2010.
Leopold, J.H. and Doornbos, H. (2009). Eindrapport kwalitatieve jaarmeting IM. Berenschot 2008.
Ministerie van Veiligheid en Justitie (2011). Brand Chemie-Pack Moerdijk - Een onderzoek naar de bestrijding van (de effecten van) het grootschalige incident. Inspectie Openbare Orde en Veiligheid The Hague, The Netherlands; August 2011 (in Dutch).
Nota hulpverlening bij ongevallen en rampen (1975). (in English: Emergency aid for serious accidents and disasters). Tweede Kamer der Staten-Generaal, 13 263 Nr. 10, Zitting 1975-1976,
OASIS (2006). POS1 Evaluation report. Open Advanced Systems for dISaster and emergency management. Version 1.0. D-TA2-10. 19 December 2006.
PWC (2011). Bepaling van de informatiebehoefte ten behoeve van de Businesscase Crisisinstrumentarium. Rijkswaterstaat
Rampenwet (1985). (in English: Law on national Dutch Disasters). Staatsblad 1985, 88.
Referentiekader Regionaal Crisisplan (2009). Projectteam Regionaal Crisisplan. ISBN 978-90-814443-1-6.
Riedijk, A., Scholten, H.J., Lassche, M. and Jacobs, C. (2008). GEO-INFORMATIE: IN LIJN DER VERWACHTING, Een evaluatie van gekoppelde processen, informatie en netwerken in de rampenoefening Warroom, Rijkswaterstaat, Amsterdam 2008.
Riedijk, A., Brooijmans. P. Jacobs, C., Lassche, R. and Verzandvoort, S. (2008). Evaluatie Rampen Oefening Eagle One, De toegevoegde waarde van geo-informatie voor rampenbestrijding, Geo-spatial Infrastructure for Disaster Management (GDI4DM). Vrije Universiteit Amsterdam, Juni 2008.
Rijk, R. van (2008). Regionaal Crisisplan en Netcentrisch werken. TNO-DV 2008 C470, november 2008.
Rijkswaterstaatworks management act (1996). Staatsblad 1996, 645. Wetbeheer Rijkswaterstaats werken. (see: http://www.st-ab.nl/wetten/0399_Wet_beheer_rijkswaterstaatswerken.htm).
United Nations (2009). World Urbanization Prospects, the 2009 revision, 25 March 2010.
US Department of Homeland Security (2008). National Incident Management System, December 2008.
US Department of Transportation (2009). Information Sharing for Traffic Incident Management. Federal Highway Administration, Ingrid Birenbaum, Report No. FHWA-HOP-08-059.
US Federal Highway Administration (2000). Traffic Incident Management Handbook, Office of Travel Management.
US National Cooperative Highway Research Program (2004). Sharing Information between Public Safety and Transportation Agencies for Traffic Incident Management. NCHRP

Report 520, K. Brooke, K. Dopart, T. Smith and A. Flannery, Mitretek Systems, Inc. Washington, DC, Transportation Research Board, ISBN 0-309-08792-9.
Vollehoven, P. van, Hulsenbek, J.A., Berg, A. van den, Mertens, F.J.H. and Visser, J.P. (2006). Brand Cellencomplex Schiphol-Oost, Onderzoeksraad Voor Veiligheid.
Ven, J. van de, Frinking, E., Rijk, R. van and Essens, P.J.M.D. (2008). Evaluatie Netcentrische informatie voorziening tijdens Voyager. TNO-DV 2007 C614, maart 2008.
Zwaneveld P., Wilmink, I., Immers, B. Malipaard, E. and Heyse, D. (2000). An overview of Incident Management projects in the Netherlands. Rijkswaterstaat, Projectbureau Incident Management.

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